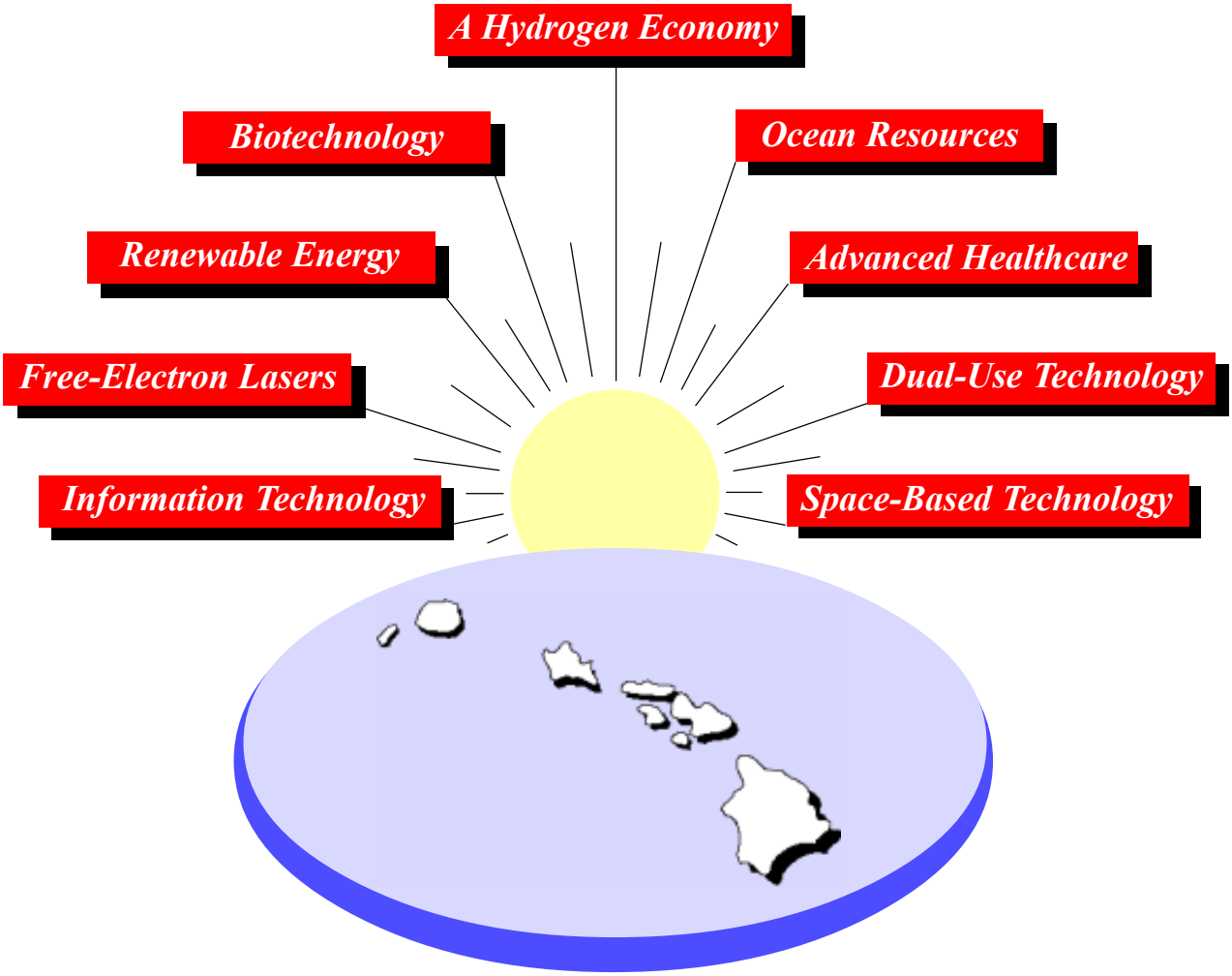
A New Millennium Growth Strategy for Hawaii's Economy: "At the Cutting Edge"



Department of Business, Economic Development & Tourism

September 2002

A New Millennium Growth Strategy for Hawaii's Economy: At the "Cutting Edge"

Table of Contents

Foreword: Joseph Blanco, Special Technology Advisor to the Governor; Seiji F. Naya, Director, Department of Business, Economic Development & Tourism 1

Introduction: Hawaii - At the Cutting Edge 3

I. Moving to a Hydrogen-Based Economy 5

II. The NELHA Gateway to Renewable Energy 11

III. Ocean Science & Technology: From Deep Water Marine Research to Coral Reef Protection 13

IV. Technological Breakthroughs via the Free-Electron Laser

- A. Market Opportunities for X-ray Crystallography 18
- B. Detecting Nuclear Weapons for Island Security 20

V. Medical Technology: Healthcare via the ICT Revolution

- A. The Kakaako Vision for Hawaiian Health and Wellness 21
- B. Are the Times Ripe for Alternative Medicine? 23
- C. Information and Communications Technology (ICT) and Computerized Medical Diagnosis 25

VI. Biotech, Infotech, and Virtual Reality

- A. Super-computing for Planning, Development, and Homeland Security 27
- B. Bio-Engineering for Cleaner and Safer Environments 29
- C. Biotechnology for Agricultural Diversification 32
- D. Mitigating Natural Disasters 34

VII. Space-based Technology: Sea, Earth, and Skies

A. Remote Sensing for Terrestrial and Extra-Terrestrial Exploration 37

B. Reaching for the Stars 39

VIII. Dynamic Derivatives of Dual-Use Technology

A. Opening Keynote Address by U.S. Senator Daniel K. Inouye (Hawaii) 41

Box 1. Dual-Use Technology at Kauai's PMRF..... 42

B. Hawaii's Strategic Role in Technology Development in the Pacific.....43

C. Concluding Assessment of Hawaii's Dual – Use Technology Potential 46

Foreword

In January 2000, the Department of Business, Economic Development and Tourism issued a New Millennium Growth Strategy document, which presented Governor Cayetano's vision for Hawaii's economic development into the New 21st Century economy, tempered by a realistic appreciation of Hawaii's assets and liabilities.

The Strategy focused on: (1) advancing existing and emerging economic activities that will most likely serve as the driving forces behind Hawaii's future economic growth; (2) increasing the supply and quality of factors that are needed to realize Hawaii's economic potential (e.g., skilled workers, investment capital, supportive infrastructure); and (3) encouraging Hawaii's industries to seize every opportunity for beneficial and innovative engagement in the New Global Economy.

In November 2001, the Office of the Special Advisor to the Governor for Technology Development issued a document which set forth a Strategic Plan for Technology-based Development in Hawaii. The document stresses that high technology is to be viewed not as an end in itself, but as a means to many economic development opportunities. It notes that the value of technology-based initiatives for economic development resides not only in establishing industries that develop high technologies, but also in promoting those industries that apply them--using spin-offs from R&D to catalyze innovation and diffusion in a broad range of industries, such as software development, communications technology, information management, techno-tourism, and Federally-mandated dual-use applications.

The two complementary publications stress that the strategy is evolving and will continue to evolve over time in response to changing circumstances and opportunities – particularly advances in far-sighted research, new and innovative technology, shifts in the U.S. and world economies, the opening up of new opportunities for Hawaii, new insights from knowledge accumulation and evaluation, and changes in community values.

Accordingly, the present document is subtitled "At the Cutting-Edge" to indicate that technology and new economy innovations are so dynamic that other sectors can readily move into the spotlight. It should be noted that many research-based activities are still in their infancy relative to Hawaii's economic mainstays of tourism and, to a lesser extent, defense expenditures. This fact is recognized in our technology strategy, which supports the integration of technological advancement in the further development and marketing of tourism and closer adherence to dual defense-commercial use application of Federal expenditures.

We hold sufficient confidence in the quality and creativity of our research establishment and the alertness and entrepreneurship of our private and community-wide sectors to feel that many of the potentials and opportunities presented here will in time emerge as beneficial and profitable augments to Hawaii's economic base. We further recognize that this limited publication will not have included many other potential technological breakthroughs. Therefore this document is issued as a guideline for future consideration and action, with the understanding that both plans and actions can change as circumstances change and our knowledge improves.

Joseph Blanco
Special Technology Advisor to the Governor

Seiji F. Naya
Director
Department of Business, Economic Development & Tourism

Introduction

Hawaii: At the Cutting Edge

In January 2000, at the dawn of a new millennium, the Department of Business, Economic Development and Tourism issued a document depicting a growth strategy for Hawaii's economy for the early years of the 21st Century. This strategy relies basically on our ability to recognize and react to the requirements of the new global economy, to upgrade our knowledge capacity, and to uplift our productivity in both public and private sectors. It suggests actions in key areas that will be instrumental in shifting our economy from one that is tradition-based and input-driven to one that is dynamically far-seeing and technology-driven. The keys, as we indicated, are economic diversification, supported by enhanced knowledge and technological innovation.

The report suggested that as tourism settles into an era of more modest growth, an expanded technology sector could become Hawaii's new growth engine. This would generate new income and revenue sources, raise Hawaii's profile in the worldwide research and technology community, and help attract interest and investment in Hawaii as a site for serious scientific research and technology activity. Moreover, an expanding technology sector can help support the spread of new technology into all of Hawaii's industries, which is critical for ensuring a competitive economy in the 21st century.

The State has sought to meet these challenges with an aggressive economic restructuring program to reinvigorate economic growth, including tax reductions, government streamlining, and regulation alleviation, aimed at enabling the private sector to improve productivity, raise competitiveness, and focus on areas where Hawaii companies have a competitive edge.

However, the September 11 terrorist attacks dealt a severe blow to the national psyche and to a Hawaii economy heavily dependent on tourism. Reductions in overseas air travel, fueled by fear of traveling by potential visitors, have negatively affected the industry and its employees.

Remedial action has been instituted and legislation passed, such as expanded capital improvements spending, a full-court press on tourism marketing, further business incentives, short-term relief, and stimulants for long-term growth. However, it should be

recognized that because of the mounting uncertainties of anti-terrorism activity, the heavy recessionary prognoses in Japan and possibly elsewhere on the globe, the fear of flying worldwide, and most recently, the resounding crash of U.S. securities markets, restoration of industry growth and economic well-being will be a painful, long-term journey.

While it should be acknowledged that for the foreseeable future, tourism will remain Hawaii's foremost income generator and employment source, there is both a necessity and opportunity to accelerate measures and activity in important parts of the economy that are not so reliant on tourism growth.

The task would be to devise a strategic planning process for economic diversification in Hawaii through a realistic assessment of Hawaii's market opportunities and resource availability. Its long-term goal would be to transform the economy from one that is externally prone to shock to one that is not necessarily shockproof, but rich in knowledge, proficient in technology, and globally competitive.

An important first step has been the issuance by the Office of the Governor's Technology Advisor of a Strategic Plan for Technology-based Development, which details steps already taken both within and external to state government to provide technology-based development. In addition to building upon the State's intrinsic strengths assets, and resources, the plan places special emphasis on encouraging and improving university, federal, and privately sponsored research in support of technology-based development, as well as on accelerating the transfer of new technology for commercial development.

Thus, the purpose of this document is to provide specific examples of research initiatives and commercialization potential, at the cutting edge as it were, with the caveat that neither Rome nor Silicon was built in a day. Further, the risk element in tech-oriented ventures (and this is not limited to dot.coms), remains high. Nevertheless, the ensuing listing, incomplete as it is, does provide exciting opportunities for expanding Hawaii's economic growth.

I. Moving to a Hydrogen-Based Economy

Hydrogen fuel holds significant potential for diversifying Hawaii's energy mix – especially in the state's transportation and distributed power generation sectors. Hydrogen produced from renewables used in fuel cells would reduce Hawaii's dependence on fossil fuels, promote higher energy efficiencies, and decrease air pollution and green house gases.

At the national level, the January 2002 announcement of a Freedom CAR (Cooperative Automotive Research) program has generated broad interest. Michigan, long the nation's auto manufacturing center, has also set forth a comprehensive program to assert leadership in producing fuel cells for vehicle and stationary applications. California has designed a unique public-private partnership program, which seeks to advance a new vehicle technology that could move toward practical and affordable environmental solutions. Other states are moving briskly in anticipation of their long-term fuel cell economies.

Hawaii's situation is unique, but no less formidable. Since the early 1970's, Hawaii has become increasingly dependent on fossil fuels, with imported crude oil and finished petroleum products from the U.S. mainland and foreign countries currently supplying nearly 90% of the State's energy needs. To reduce this dependence, as well as counteract high consumption prices, the State has been exploring ways to develop and use renewable energy derived from its abundant solar, wind, biomass, and geothermal resources, as well as from hydrogen experimentation. Hydrogen as a storage medium and transportation fuel can play a key role in allowing penetration of renewables in the energy mix. The eventual large-scale use of hydrogen fuel will require low-cost production; compact, safe, and cost-effective storage capabilities; and hydrogen-based energy infrastructure.

Fuel cell technology isn't new; it has been around for more than 150 years. The first experimental fuel cell was built in 1839, but interest in fuel cells as power generators did not occur until the 1960s, when NASA used the first commercial fuel cell to provide an alternative source of power for the U.S. space program. However, refining fuel cell

technology from powering a space shuttle to powering people's homes will take much more time and innovation.

Hawaii's geographic and energy situation offers a unique opportunity for the State to play a lead role in the development of these technologies. With its vast renewable energy resources, energy application expertise, constrained geography, policy directives toward achieving increased energy self-sufficiency, and Asia Pacific location, Hawaii is a natural "testbed" for the deployment and commercial scale demonstration of hydrogen and fuel cell technology. The state could also significantly benefit, both environmentally and economically, from the utilization of hydrogen in its transportation and power generation sectors.

Mindful of these potentials, Hawaii's State Legislature enacted several business and tax incentive measures to accelerate the state's transition to an energy future based on renewable resources, and tasked the state's Department of Business, Economic Development and Tourism (DBEDT) to assess the feasibility of large-scale commercial utilization of hydrogen in Hawaii. Completed at the end of 2001 in conjunction with the University of Hawaii's Natural Energy Institute (HNEI) and Sentech, Inc., the assessment found that hydrogen, based on renewable resources, can be a competitive fuel provided that expected advances in fuel cell technologies are achieved.

The investigation also sought to identify life-cycle pathways with the strongest potential for incorporating hydrogen into the Hawaiian energy system in scenarios that utilize Hawaii's indigenous energy resources to generate power – specifically geothermal, wind, and biomass energies – as well as imported liquefied natural gas, or LNG (as an alternative energy supply).

Based upon preliminary data, the study suggests that geothermal-produced hydrogen (on the Big Island), and biomass-produced hydrogen (on the Big Island, Maui, and Kauai) could all compete with gasoline at current prices. Large-scale use on Oahu would likely require importation from one of the other islands or development of a LNG infrastructure.

The sensitivity analysis reaffirmed that the study's assumptions on most of these parameters were conservative and that LNG, geothermal, and biomass-produced hydrogen could become a competitive transportation fuel.

For the State, a long-term "roadmap" of activities that incorporates the unique attributes of each of the Hawaiian Islands and encourages business and government statewide to work in partnership for further research, experimentation, and demonstration is being developed. What is called for are:

1. A comprehensive engineering and market study for the production of hydrogen on Hawaii and Oahu, using actual cost data from industry to evaluate future options for hydrogen energy for clean transportation, fleet transportation, distributed electricity, remote power, and domestic applications.
2. Engineering assessments of biomass for Maui and Kauai, evaluating gasification of biomass for hydrogen production, as well as possibilities for inter-island fuel exports.
3. Pilot projects to install multi-megawatt electrolyzers to produce hydrogen from indigenous resources on the Big Island to validate performance, reliability, and economies of producing hydrogen via electrolysis or gasification using geothermal energy, biomass feedstock, and potential wind energy.
4. Pilot projects that include distribution of hydrogen produced on Hawaii to other islands, testing the feasibility of "exporting" hydrogen from Hawaii to one or several other islands with promising applications.
5. Creation of public/private sector partnerships to develop a hydrogen infrastructure by promoting and opening up energy markets for hydrogen and fuel cells, encouraging technology transfer and investment, educating the public, and attracting requisite industry and Federal funding.
6. Over the longer-term, the task of transforming the State toward the envisaged energy efficient, environmentally friendly economies will involve: developing a hydrogen production/storage infrastructure to produce hydrogen fuel from renewable energy sources. This would require: (a) evaluation of policy options to promote industry

investment in hydrogen infrastructure; (b) market feasibility studies for the production of hydrogen on all major islands; and (c) assessment of the potential costs/benefits of hydrogen fuel to consumers.

To date, and in concert with these recommendations, the following activities are being pursued:

- Development of the Hawaii Distributed Energy Resources Center, funded by a $3 million U.S. Dept. of Energy grant secured by U.S. Senator Daniel Inouye, is underway at the NELHA Gateway. The Hawaii DER Center provides a venue for alternative energy technology development, including the design, testing and evaluation of hydrogen fuel and fuel cell technologies.
- In January, 2002, The Hawaii Natural Energy Institute (HNEI), in partnership with UTC Fuel Cells (the world leader in fuel cell production and development for commercial, transportation, residential and space applications), the U.S. Office of Naval Research, and Hawaiian Electric Company, announced plans to open a hydrogen fuel cell research facility on Oahu. The facility would enable HNEI to evaluate the performance and reliability of fuel cells, promote the development of low-cost fuel cells, and accelerate their adoption for specific commercial and military applications. Most recently, Stuart Energy joined this partnership and is helping support installation of an electrolyzer to generate hydrogen for fuel cell testing.
- Through the US Department of Energy's (DOE) State Energy Program, DBEDT has been competitively awarded $150,000 for the first increment of a three-year, three-phase project to develop a Hydrogen Power Park on the island of Hawaii. With HNEI as implementing partner and other partners including UTC Fuel Cells, HECO, HELCO, the Gas Company, Stuart Energy, Sentech Inc, and Sunline Transit, this cost-shared project will involve the design, installation, and operation of an integrated hydrogen production, storage and fuel cell facility. A key element of this effort will be to work with local authorities to identify and solve

permitting issues that may be barriers to the introduction of a hydrogen infrastructure.

- In August 2002, with support from DBEDT, HNEI hosted a Hydrogen Partnering meeting. This workshop, held on the Big Island and attended by representatives from US DOE, the National Laboratories, US DOD, industry, the local utilities and University of Hawaii identified potential projects to move development of the hydrogen infrastructure forward, From more than 20 projects initially identified, the following were among those deemed most promising:
    - **Big Island –** using wind and geothermal generated electricity curtailed during off-peak periods when the electric grid cannot use the power, to generate hydrogen at the Hawaii Distributed Energy Center located at NELHA Gateway.
    - **Big Island –** use of small-scale wind, photovoltaic and biomass to generate hydrogen, which in turn would be used to meet the power requirements of small villages or communities that were not connected to the grid.
    - **Kauai –** production of hydrogen which would be stored and then used for a variety of power applications, including stationary power for the Waimea Technology Center, the PMRF, hospital, schools and the transit system.
    - **Oahu –** generation of hydrogen from multiple energy pathways, including reforming SNG supplied by The Gas Company through its existing pipeline and PV hydrogen generated from the 200kW photovoltaic array planned for the Pearl Harbor Navy base.
    - **Oahu & Big Island –** use curtailed geothermal power to produce hydrogen using an electrolyzer. The hydrogen would be stored in high pressure gas cylinders or hydride storage tanks and then shipped via inter-island barge to Oahu, where is would be used as a transportation fuel.

Hydrogen has the potential world-wide to revolutionize the way we produce and use energy. Hawaii, in turn, with its growing focus and expertise in the development and use of renewable energy resources, has the opportunity to become a world leader in the transition from a fossil-fueled energy society to a cleaner energy future. Hydrogen is the link between renewable energy and clean transportation fuel. The roadmap defined by this study and successful implementation of identified pilot projects will enhance Hawaii's leadership in the research and applications of hydrogen fuel, which in turn will likely attract significant economic investment to the state.

II. The NELHA Gateway to Renewable Energy

As an island state with no indigenous fossil fuel resources, Hawaii needs to encourage the development of renewable energy technologies. It already ranks high among states measuring non-hydro renewable energy as a percentage of total energy consumed. The NELHA Gateway Project, located at the entrance to the Hawaii Ocean Science & Technology (HOST) Park of the Natural Energy Laboratory of Hawaii on the Big Island, will serve as a premier center for research and development, testing, demonstration, and commercialization of technologies supporting Distributed Energy Resources (DER), Ocean Sciences, Marine Bio-products, and related fields, and also will provide education, outreach and techno-tourism activities for Hawaii residents and overseas visitors in each program area.

To further these initiatives, an initial construction funding grant from the U.S. Department of Energy (USDOE) will provide an opportunity and foundation for a national test bed dedicated to development, testing, demonstration and deployment of cutting-edge distributed energy technologies. The groundbreaking for the NELHA Gateway Distributed Energy Resources Center was held on August 27th 2002 and construction of the center is slated for completion by October 2003.

NELHA's direct access to both deep cold and warm surface seawater, high solar insolation, and proximity to the Kona International Airport and Kailua-Kona/South Kohala resorts make the location an ideal site for the Gateway Project. Its other locational advantages for product research, development, and ultimate commercialization include:

1. Hawaii's current position as a recognized national front-runner among states utilizing renewable energy resources, which enhances its ability to secure both public and private sector funding.
2. Distributed Energy Resource (DER) hybrid energy projects that make Hawaii a model for research, development, demonstration and deployment, and that afford partnering opportunities to maximize the availability and distribution of energy resources.
3. Its geographical proximity to potential markets in the Asia-Pacific region.

4. Its ability to provide a model demonstration site for less developed economies exclusive of the difficulties encountered when working outside the United States.

The early focus of the project will be to serve as an incubator for companies involved in renewable/distributed energy generation and related fields and to help foster key industry and national energy lab partners to develop sustainable programs and activities.

In this area, a proposal considered by Congress through Senator Inouye to fund a joint effort between New Mexico Tech and NELHA through an Integrated Distributed Generation Applications and Deployment Program was approved, and funds appropriated through the U.S. Department of Energy have been approved. NELHA is also partnering with the Hawaii Natural Energy Institute of the University of Hawaii, and collaborations with other academic institutions and industry partners are currently being developed.

Further, NELHA affords other highly promising opportunities as a "centerpiece" for commercial development that will support various ocean-related theme activities. Examples include:

- An ocean-themed exhibit, aquarium facilities, and associated commercial activities.
- A marine research laboratory and support facilities.
- Ocean-themed education and outreach facilities.
- Applied research, development and demonstration projects involving cutting-edge ocean technologies.

Commercially viable enterprises that are compatible with and enhance the theme of the proposed Ocean Centerpiece.

III. Ocean Science and Technology: From Deep Water Marine Research to Coral Reef Protection

The University of Hawaii's Underwater Research Laboratory (HURL) made worldwide headlines in August, 2002 when its pair of PISCES class deep-diving manned submersibles discovered a Japanese "midget" submarine just outside of Pearl Harbor. The submarine was part of an advance force that included five similar vessels that were deployed to seek and destroy American warships. The sub was reported sunk by the destroyer USS Ward an hour before the Japanese air attack on Dec. 7, 1941, but until now the report has been unconfirmed. The discovery has been called the second most historic sunken archeological find (after the Titanic) in modern times.

HURL is just one example of the dynamic assets available to Hawaii's ocean science and technology industry, which has grown from about $20 million in 1980 to $117 million in 2000. Commercialization of Hawaii's ocean-oriented research and development programs has been a major milestone in this growth. Local companies are making scientific instruments designing software packages and developing demonstration projects for global markets, including hyperspectral and multispectral imaging services for coral reef mapping and other applications, utilization of deep ocean water, high-resolution ocean floor maps integrating sidescan sonar and bathymetry, and software to support the worldwide cable industry.

The industry is founded on Hawaii's natural advantages. The Island chain's volcanic origin and lack of continental shelf, ready access to pathogen-free, nutrient-rich deep water, and an impressive variety of ecosystems make it an unparalleled natural laboratory for ocean research and development. An increasing number of research programs and commercial ventures are capitalizing on Hawaii's ocean resources to increase basic scientific knowledge, develop applied R&D programs, and commercialize products and services.

For example, the University of Hawaii's School of Ocean and Earth Science and Technology (SOEST), the nation's third-largest oceanographic institution, competes with the top research schools in the country and attracts more than $50 million in grants each

year. SOEST and its affiliated research institutes support a broad range of marine and ocean-related R&D programs, from ocean circulation models to primary productivity and mineralization processes.

The Hawaii Undersea Research Laboratory mentioned above operates two deep-diving manned submersibles and several remotely operated vehicles (ROVs) as part of a nation-wide system of underwater research centers funded by the National Oceanic and Atmospheric Administration. Its mission is to study deep-water marine processes in the Pacific Ocean. HURL builds its research program through an annual request for proposals. Projects are selected through peer review and by a scientific advisory panel. In addition, HURL accepts funded requests from private, state, or federal agencies and participates in international collaborative research projects in the Pacific.

The Hawaii Institute of Marine Biology (HIMB), located on a coral reef preserve in Kaneohe Bay, supports research in coral physiology and reef ecology, the behavior and population dynamics of fish, marine endocrinology, aquaculture and marine mammals. This research will be strategic in confronting many of the issues highlighted in the current international concern on the sanctity of coral reefs. The new Pauley-Pagen Laboratory at HIMB focuses on two additional aspects of tropical marine biology – biodiversity and biotechnology.

The Marine Bioproducts Engineering Center (MarBEC) represents a partnership between the University of Hawaii at Manoa and the University of California, Berkeley with additional collaboration from leading national laboratories, research centers and museums, and industry partners. MarBEC is building a foundation of applied research, education and technology transfer to support a marine biotechnology industry of increasing commercial and national importance.

Hawaii is also home to a number of non-profit ocean research organizations. For example, the Oceanic Institute, renowned for its pioneering work in aquaculture, is a private, not-for-profit research and development organization dedicated to marine aquaculture, biotechnology and coastal resource management. The Pacific International Center for High Technology Research (PICHTR) also promotes and develops technology appropriate to the marine and tropical environment of the Asia-Pacific region, with an emphasis on applied research and development of renewable energy technology

(including Ocean Thermal Energy Conversion, or OTEC), environmental planning and remediation activities.

Science and Technology International (STI), one of the companies in Hawaii's emerging remote sensing sector, acquires and processes spectral information about objects to facilitate underwater coral discrimination for assessment of reef health, monitors pollution caused by oil slicks and ground runoff, and count whales, among other applications important to coastal managers.

The Common Heritage Corporation (CHC), led by Natural Energy Laboratory of Hawaii Authority (NELHA) founder Dr. John Craven, is developing a variety of deep ocean water applications, including growing more than 100 fruits and vegetables in soil cooled by pipes carrying cold deep seawater. Techniques developed by CHC have yielded dramatic increases in crop yield (three grape crops per year instead of one) and show promise for countries with ready access to deep cold water.

Hawaii companies have developed products that support the cable industry in three important areas: cable design, seafloor mapping, and cable laying. CableCAD is a product of Structural Solutions, Inc., which brings computer-aided design of cables to the personal computer. CableCAD is a comprehensive cable design tool for laying out cable geometry and a powerful analysis program. The speed and versatility of this new cable software reduces design time and lowers design costs.

Hawaii is also developing a worldwide reputation by providing sophisticated computer programs to integrate seafloor mapping data such as sidescan sonar and bathymetry. Mapping the seafloor for the cable industry is just one of many applications supported by software and support systems developed by Oceanic Imaging Consultants, Inc.

Hawaii's third area of expertise focuses on providing solutions that improve the cable industry's ability to install cables in an efficient and cost-effective manner. Makai Ocean Engineering, Inc. has developed cost-saving computer systems to plan, monitor and control (in real-time) the installation of cables and cable systems. The company is also the world leader in the design and installation of large pipelines for bringing deep ocean water to shore from depths of as much as 3,000 feet. Makai has designed and supervised the installation of all water pipes at NELHA, and supports the development of

technology to utilize deep cold water (from the ocean or lakes) to provide industrial air conditioning. NELHA labs and offices are cooled efficiently in this manner at a cost saving of about $4,000 per month. Makai also installed a similar award-winning system at Cornell University in New York State utilizing deep cold lake water.

Oceanit, a Hawaii-based engineering and research company focusing on biotechnology, information technology, and environmental and industrial technology, has developed the innovative flexible pipe diffuser that conducts sediments contained in dewatering effluent from harbor construction to the harbor bottom, thereby minimizing plumes in coastal waters. They have also commercialized University of Hawaii research to produce the only available immuno-reactive test kit designed to detect ciguatoxin, in fish flesh, which can cause neurological illness in humans.

Hawaii is also becoming a center for microalgae research and production for the pharmaceutical, nutraceutical and aquaculture feed supplement markets, among others. Cyanotech Corporation is currently the world's largest producer of Spirulina – a high value nutritional supplement for the health food industry. They also produce natural astaxanthin, a powerful antioxidant, and phycobiliproteins, which are fluorescent pigments used in the immunological diagnostics market. Mera Pharmaceutical's (formerly Aquasearch) photobioreactor technology is used for astaxanthin production and other microalgae research and development that will provide opportunities for pharmaceutical applications. Both companies are located at NELHA.

A third microalgae company, Micro Gaia, Inc., backed by the Fuji Chemical Industry Company, Ltd., selected Maui as the site of its first U.S. facility because of the abundant sunshine and water, excellent support facilities of the Maui Research & Technology Park, local start-up support, and high-tech tax incentives. Using breakthrough Bio-Dome closed system technology, the company also produces astaxanthin, as well as arachodonic acid, as primary products.

An affiliate program of NELHA since 1995, the National Defense Center of Excellence for Research in Ocean Sciences (CEROS) seeks to advance innovative concepts and new approaches to technology, while fully leveraging existing facilities and infrastructure in Hawaii to demonstrate commercial utility for the Department of Defense (DOD). Its mission is to support the DOD technology requirements; encourage leading

edge R&D in ocean sciences and technology in Hawaii; foster use of ocean R&D facilities in Hawaii; and provide an interface between specialized small businesses with expertise in ocean-related R&D and DOD users of advanced technology. Between 1993 and 2002, the CEROS Research Programs funded a total of 140 projects at a value of over $54.4 million. The projects have involved a wide variety of marine technologies, including advanced ship design, signal processing, remote sensing, safety equipment, electronic charting and detection systems.

These are just a few examples of areas in which Hawaii demonstrates leadership in ocean science and technology. Drawn from the private, academic and government sectors, these examples provide a window on Hawaii's growing reputation as a leader in the field and suggest many additional areas for cutting edge technological research and development.

IV. Technological Breakthroughs via the Free-electron Laser

A. *Market Opportunities for X-ray Crystallography*

Hawaii, which has already generated world-acclaimed breakthroughs in the cloning of mice, is on the verge of yet another technological advance. Dr. John Madey, Professor of Physics and Astronomy at University of Hawaii, has developed a process utilizing a high energy light source (a Free-Electron Laser, or FEL) that will enable researchers to gain a three-dimensional understanding of how proteins are structured and thereby how they are likely to bond and react with other substances.

Why and how is this important? The process, termed x-ray crystallography, involves bouncing X-rays off of molecules in a crystal to produce a diffraction pattern, and then analyzing this pattern to determine the structure of the molecules. FEL technology, invented by Dr. Madey, provides a highly cost-competitive alternative to synchroton energy sources currently employed at national research laboratories. Insights gleaned through this analysis will significantly improve basic understanding of the synthesis and functionality of proteins and other critical biological structures. They also will provide useful information on the basic biochemical mechanisms underlying sickness and health, and potentially on other non-biological structures of interest to materials scientists and other developers of advanced electronic and structural materials.

FEL-based X-ray crystallographic systems are potentially of great interest to pharmaceutical companies. Since many diseases are the result of abnormalities in the amount, shape or function of proteins, pharmaceutical companies need to determine the three-dimensional structure of proteins. Knowledge of protein structure is essential to understanding how a protein functions or interacts with other proteins, and to determining how potential drugs could be designed to bind to proteins and thereby change their behavior. Pharmaceutical companies can use knowledge of protein structure provided through X-ray crystallography to design and develop more effective drugs more efficiently. The FEL capabilities and expertise at the University of Hawaii give the state a competitive edge in addressing the growing demands of and opportunities in pharmaceutical and proteomics markets.

X-ray crystallography technology can also help advance industrial applications. Research into the properties and structure of materials and determination of their elemental composition (collectively known as "materials research") can lead to the discovery of catalysts and the characterization of materials used in the development and manufacture of new chemicals, semiconductors, steel, cement, plastics and rubber. X-ray crystallography greatly improves the process of discovering novel materials and chemical processes, allowing companies to reduce costs, increase technological innovation, and develop new products based on proprietary materials.

The University's goal in commercializing FEL technology is to develop a private facility in Hawaii that could pioneer both the hardware and protocols for X-ray crystallography and X-ray microscopy. Once established, one business model would allow Mainland pharmaceutical companies to send drugs to Hawaii for analysis. Another model would establish the Hawaii facility as a prototype and then create other centers nationwide. Venture funding from Hawaii-based sources or national firms would be sought to provide start-up capital. Development partners would be identified to broadly license the technology, fund further research and development at the University, support and perform commercial R&D, and bring the technology to market – both domestically and internationally.

B. ***Detecting Nuclear Weapons for Island Security***

FEL technology can also play an instrumental role in supporting homeland security. Under a $50 million grant from the Nuclear Treaty Program Office, a research group at the University of Hawaii is working to develop a portable sensor to detect clandestine nuclear weapons testing. Described by the principal investigator for the project, Dr. John Madey, as "a molecular bar-code reader," the sensor could continuously test the air for nuclear particles dispersed into the atmosphere by a nuclear explosion – even if the detonation were held underground.

Current nuclear testing sensors collect radioactive particles that have drifted downward from the atmosphere, and thus can take up to a week or more to collect and analyze such data. Using a FEL, the University of Hawaii-developed sensor will be able to instantaneously scan air particles and distinguish radioactive isotopes from their benign cousins, thus alerting monitoring stations to any airborne radioactive materials. A prototype of this remote imaging system will be operational within two to three years, and will initially be tested at the Pacific Missile Range Facility on Kauai.

Research underway will probe into an increasingly wide range of spin-off applications. For the current focus on airport security, development of portable laser equipment will enable screeners to detect not only nuclear particles but also chemical and possible biological hazards. This same laser sensor technology can also be used to monitor environmental conditions and air quality more rapidly and accurately, as well as to screen baggage and cargo on planes and ships.

V. Medical Technology: Healthcare via the ICT Revolution

A. *The Kakaako Vision for Hawaiian Health and Wellness*

The Plan: to capitalize on Hawaii's location and diverse mix of people, which make it an ideal laboratory for scientists to test and compare medical diagnoses, health treatments, and wellness regimes.

The Goal: to make the John A. Burns School of Medicine (JABSOM) the best in the world with an Asia-Pacific focus; to attract millions of federal research dollars into the state; and to improve the health and well-being of residents.

The Means: the University of Hawaii's new multi-million-dollar Medical campus at Kakaako, with its visionary dean and augmented specialized research faculty.

Literally at the cutting edge and well before the much anticipated ground-breaking at Honolulu's waterfront, Dean Edwin Cadman has spelled out his vision for stimulating Hawaii's physical, intellectual, and economic health. This approach will build on the school's academic and research strengths, but will also address new challenges, such as in Native Hawaiian health, and new opportunities such as research on complementary and alternative medicine.

A key focus will be to improve the health of Native Hawaiians, rated among the poorest in the nation, through a department that specifically addresses their health needs and brings in federal research dollars to support related research. The medical school also plans to investigate the molecular genetics of disease which could revolutionize health care for Native Hawaiians and other ethnic groups.

Tapping into the state's ethnic diversity, JABSOM researchers will seek to pinpoint which genes predispose people to certain diseases, with a view toward developing blood tests that will signal an individual's likelihood of getting a disease. This program will have the capacity to identify people at high risk for disease. By examining the proteins and DNA of individuals who have, for example, heart disease, diabetes, or colon cancer, a single blood test will be developed that will be able to predict probabilities for heart disease, cancer, stroke, and diabetes. This information can be used to design proper diets that can prevent the onset or recurrence of the disease.

Located at the crossroads of the Pacific, Hawaii is particularly vulnerable to potentially fatal infectious diseases. The recent dengue fever outbreak is a good example, while the arrival of the West Nile virus in California poses a major threat. The state is also seeing more imported diseases that once were considered eradicated, such as leprosy and penicillin-resistant tuberculosis. It has been noted that the University once had an outstanding program in infectious disease epidemiology, with some of the foremost experts in the world working on yellow fever. JABSOM intends to re-focus on infectious diseases that threaten the state and nation, as well as tackle issues related to Hawaii's rapidly aging population, upgrading an already strong geriatrics division. Building upon Dr. Ryuzo Yanagamachi's path-breaking research in cloning, the university will also encourage further research to determine how this method can lead to a better understanding of how genes interact to produce a disease.

In addition, JABSOM intends to embark on one of the newest concepts in medicine: looking at human health as part of the broader environment. As a confined island "laboratory" with 11 of the world's 13 climate zones, Hawaii makes an ideal place to study the impacts of ecosystem disruption and the resulting effects on human health. This program will examine how changing ecological systems affect the health of communities and individuals, and the impact that perturbations in our environment can have on our health.

Finally, as the JABSOM expands its programmatic base, it will strive to achieve research excellence in both basic and clinical research initiatives, build new and innovative infrastructure, increase the School's competitiveness to secure extramural funds, and help to recruit, develop and support promising junior faculty.

B. ***Are the Times Ripe for Alternative Medicine?***

A Harvard Medical School survey indicates that most Americans, particularly young adults, are using some form of alternative medicine, and that this trend suggests an increased demand for complementary and alternative medicine therapies that will affect all facets of health care delivery over the next 25 years.

Complementary and alternative medicine includes a wide variety of therapies – from acupuncture, herbal supplements, massage and chiropractic care to spiritual healing, aromatherapy, and imagery. Some of these techniques are recommended by some doctors, but in general, alternative therapies are not used in mainstream medicine because they have not been adequately tested in controlled clinical trials.

In Hawaii, an outstanding example of this new reliance on alternative therapies is the widespread popularity of **noni,** or the fruit or derivative of the noni plant.

Judging from its extensive website, the current insurge of noni has spread beyond Hawaii into the U.S. mainland and to other Western societies. Noni juice is being touted as a "magic drug", capable of curing or preventing HIV, cancer, diabetes, rheumatism, blood pressure, cholesterol, allergies, heart rhythm abnormalities, chronic inflammation, and aching joints. The website has gathered testimonials from numerous users, including physicians, as to noni's benefits. For example: "Noni helps improve the entire spectrum of your health, not just a single problem. Noni helps your body generate life force… and revives your body's natural ability to heal itself."

However, while some scientific evidence exists regarding these therapies, there are key questions that need to be addressed through well-designed scientific studies – questions such as whether these therapies are safe and how effectively they combat the diseases or medical conditions for which they are used.

At the University of Hawaii's Medical School, a new Department of Complementary and Alternative Medicine (CAM) is being established. Its goal is to become a national leader in medical education and research integrating western and alternative medicine practices such as acupuncture, chiropractic, herbal remedies and homeopathy. According to Dean Edwin Cadman, JABSOM is committed to conducting both basic and applied research related to complementary and alternative therapies in areas of particular interest to Hawaii and the Pacific region, as well as to educating the

next generation of physicians about the potential risks and benefits of complementary and alternative therapies.

An in-depth cultural and ethnographic study of native Hawaiian healing traditions is needed to avoid their dilution or misrepresentation in evaluating CAM therapies, and the school will collaborate with the Native Hawaiian and Health Ecology specialist to address this need.

JABSOM is further interested in exploring models of integrative care teams strategically placed in Hawaii's major hospitals, large medical groups and /or health maintenance organizations, and will seek to develop relevant educational materials for clinicians, researchers, educators and consumers of health care in Hawaii. Its goal is to identify unique research opportunities and to establish collaborative partnerships linking Hawaii-based researchers with national and international investigators from both the public and private sectors. In support of this goal, JABSOM is working to develop a collaborative partnership with the Osher Institute and the Division of Research and Education in Complementary and Integrative Medical Therapies at Harvard Medical School that would focus on joint interests in Complementary and Alternative medicine. The initial focus in Hawaii would be on traditional Chinese medicine and botanicals – both land and marine – indigenous to and /or grown in Hawaii. The goal is to acquire a multi-million dollar grant from the National Institutes of Health that would help establish Hawaii as a P-20 Center supporting major intervention-base investigations, pilot studies, investigator training, and community-based research.

Regarding **noni,** Dr. Katalin Csiszar of the new CAM department is working with the Cancer Research Center on the chemistry of the noni plant. Preliminary research indicates the plant has potential as a significant medicinal agent, but much more research is needed to understand how it affects normal and abnormal cells. It is anticipated that results of this research will lead to the development of an interactive environment that will attract biotechnology partners who can then follow up on translating molecular pharmacology data into drug discovery and development programs, as well as a closer analysis of the claims made for noni's medical and health benefits.

C. *Information and Communications Technology (ICT) and Computerized Medical Diagnosis*

At the Laboratory of Intelligent and Parallel System (LIPS) of University of Hawaii, computer simulation is being used to validate the use of soft lasers in tumor detection. The approach is to use Near Infrared (NIR) lasers to replace the traditional and potentially harmful X-ray in Computed Tomography technology.

A validated simulator (together with 3-D visualization), executing on supercomputers and capable of high-resolution, life-size tissue models, is being used to conduct virtual computed experiments. Such virtual experiments yield new insights into bio-photonics and suggest alternative designs for the next generation prototype devices and systems.

By leveraging the supercomputing power at the Maui High Performance Computer Center with the expertise and basic technology skills of the University Laboratory, it will be possible to create 3-D visualization, allowing doctors to extract volumetric data from CT, MRI, CFD and PET scans to generate images of anatomical structures within the human body. In particular, the fusion of artery angiograms with endoscopic ultrasonic images can yield a geometrically correct 3-D model, reconstructing the inner wall of an artery and thereby facilitating a virtual "fly-through" of the vessel with medically precise positioning. Conventionally, physicians have been unable to secure such an advantageous visualization during operations. The longer term R&D goal is to develop a useful clinical instrument to perform soft laser mammography and eventually, laser computed tomography for the head or the entire body.

The rapid proliferation of information and communication technologies is impacting the healthcare industry. ICT will enable healthcare services to be delivered more rapidly and efficiently to an increasingly mobile and health-conscious population. For example, portable biostatistic monitoring units and sophisticated biomedical instruments are enabling real-time acquisition of personal health data; while computer analyses, simulation modeling and graphic and virtual displays using these data are providing rapid and insightful feedback to both patients and healthcare providers via personal computers, mobile phones, and other state-of-the-art telecommunications technology.

The integration of computing and communication with health/wellness care (including western medicine, Oriental medicine, natural healing and dietary supplements) points to further interdisciplinary R&D, education, and training. The boundaries between previously independent fields, like physiology, biochemistry, imaging and system engineering, will fade due to continuous interchange and integration. Access to data/information in a universal form, sharable across the net and usable by the microprocessor software in the patients' homes or physicians' offices, will be the driving force for such interdisciplinary integration.

This has been the principal rationale for the rise of many biomedical science and engineering programs and departments at many universities (e.g., Harvard Medical School, MIT, UC Berkeley, UCSF, and the University of Washington), at institutions (e.g., National Cancer Institute/NIH and the Office of the U.S. Air Force Surgeon General), and for funding agencies (e.g., NSF and Whitaker Foundation).

In light of this, creating an interdisciplinary program of biomedical technology in Hawaii would promote collaboration and attract major research funding (e.g., from DoD, NSF, NIH or Whitaker Foundation), as well as stimulate productive interaction with local partners such as Tripler Army Medical Center, the Maui High Performance Computing Center, and any of several major hospitals in the state. Additionally, the National Institutes of Health (NIH) has targeted new funding for several centers of excellence and for educational programs leading to a master's degree in health communications and media informatics.

By enabling 3-D image visualization on the World Wide Web and aiding product design with computed experiments, the development of bio-medical engineering programs at the University of Hawaii would provide strategic support for the UH Medical School's new center at Kakaako, enable virtual-presence telemedicine for Hawaii's VA hospital, enhance simulation tools and skills for laser physics research, and provide computational support to augment the Pacific Disaster Center's emergency response capabilities.

VI. Biotech, Infotech and Virtual Reality

A. *Supercomputing for Planning, Development, and Homeland Security*

Development of supercomputer capabilities at the University of Hawaii's College of Engineering (CoE) of the University of Hawaii (UH) offers real world promise for solutions in government planning, business development, and homeland security. A proposed extension of the "Virtual Hawaii" Project coordinated by Professor David Y. Y. Yun at CoE's Center for Advanced Computing and Virtual Experiments (CACAVE) is aimed at simulating, generating, visualizing, and utilizing three-dimensional models of buildings and towns for activities ranging from architectural design and urban/resource planning to building access control and emergency response management.

The project would build on dramatic advances in image acquisition, super-computing and visual display that have enabled the transformation from paper-based and digital data to interactive, 3-D virtual models that can be manipulated and navigated in real time. It would enable immersive virtual walk-throughs to be conducted and multiple what-if scenarios/alternatives to be addressed.

It would also bring to bear several "Hawaii-grown" technologies developed under Professor Yun, including content-based image retrieval, image registration, data fusion, and virtual laboratory, as well as 3-D information extraction, retrieval and visualization. When combined with GPS (Global Positioning System) data, the model-base and virtual simulation capabilities can be used as visually realistic 3-D scenes for such activities as land-use and urban planning, environmental monitoring, civil defense, terrorism control and disaster management.

The project approach calls for research, with the acquisition of a range camera for 3-D image capture to significantly enhance the ability of developing 3-D structure and object models; development, concentrating on tool enhancement and system integration to achieve the envisioned capability of 2-D and 3-D data fusion and automatic model building by super computer simulation; and deployment, to apply prototype systems to solve specific problems. Application of this project approach, focusing on emergency response and on architectural design, could demonstrate the capabilities of system infrastructure.

This project will be implemented through university-business-government partnership, augmented by a highly trained workforce that is familiar with the new techniques, their functionalities and applications, as well as end-user needs, and supported by training opportunities extending beyond UH Manoa and UH Hilo to the Community College System.

From its inception, it is anticipated that this project will develop the necessary tools, underlying systems and technology infrastructure to provide a critical boost to public planning and business prospects, while simultaneously expanding research and enriching educational opportunities at the University of Hawaii. Private sector beneficiaries would include local companies in architecture, construction, engineering and information technology. Uses beyond commercial applications would include civil defense or emergency response for governments and special operations or terrorism control for the military, together with applications in urban/resource planning, land use and environmental control, and shoreline, reef, and marine environmental monitoring – all with the purpose of generating products and services for deployment to other areas within the Asia-Pacific region.

B. ***Bio-Engineering for Cleaner and Safer Environments***

Advances in bioremediation – the application of biological processes to address environmental problems – gives promise for a new technology that not only addresses Hawaii's increasingly critical problem of waste disposal, but also offers a means for preservation of vital agricultural infrastructure.

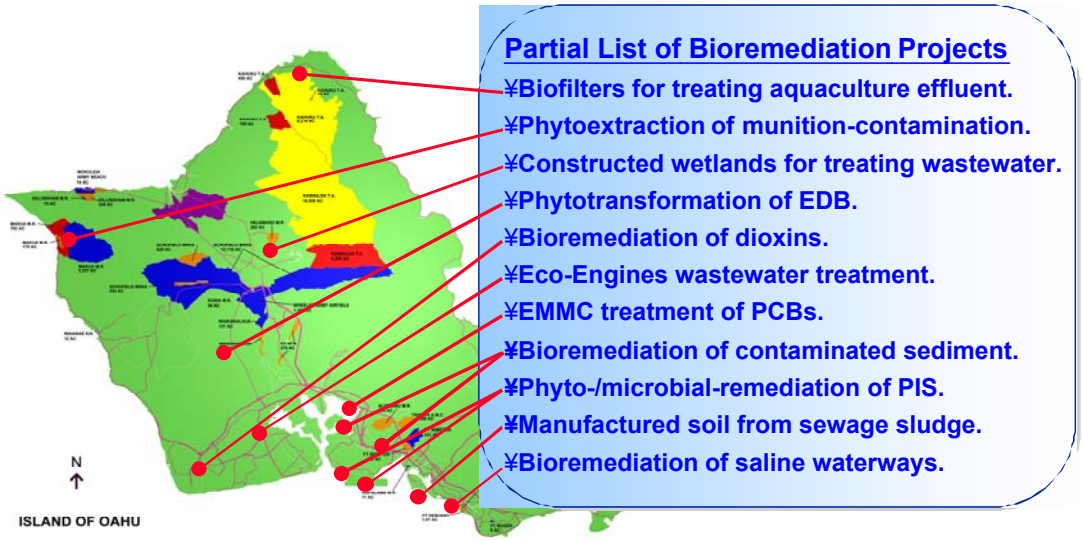
Relying on biological systems to effect desired changes in the environment is not a new concept. Wastewater treatment and composting have long been used as biological approaches to handling human and other organic wastes. However, recent developments in molecular biology and bioprocess engineering at the University of Hawaii under the Agriculture-Based Remediation Program, offer new methods of selecting organisms and designing innovative processes so that greater amounts and wider varieties of chemicals and wastes can be treated in less time. Advances in environmental biotechnology now enable the cleanup of both water and land polluted with petroleum and other products. Discoveries in microbial and fungal systems, and advances in manipulating conversion pathways through added metabolites, have produced organisms that can treat chlorinated compounds, polynuclear aromatics, and pesticides.

The advantages to using bioremediation over other approaches are clear-cut. Most bioremediation processes can be performed *in situ*, which reduces cost and disruption to operations. Unlike traditional disposal approaches, bioremediation generally aims to decompose waste materials, and therefore represents a permanent strategy, minimizing long-term liability. Bioremediation is also highly versatile. It can be combined with other treatment options to address complex, mixed wastes. The emphasis on biological systems and biological processes makes bioremediation especially suitable to agribusiness growth in Hawaii. Given the aforementioned advantages, bioremediation could be a key component in developing valuable technologies and services to protect and preserve vital agricultural infrastructure, while also contributing to protection of the environment and natural resources.

The bioremediation technology most suitable for a specific site is determined by several factors, such as site conditions, indigenous microorganism population, and the type, quantity, and toxicity of contaminants present. Some treatment technologies involve the addition of nutrients to stimulate or accelerate the activity of indigenous microbial

communities. If the biological activity needed to degrade a particular contaminant is not present at the site, suitable microbes from other locations, called exogenous microorganisms, can be introduced and nurtured. In Hawaii, other technologies being demonstrated are phytoremediation – or the use of plants to clean up contaminated soils and ground water – and fungal remediation, which employs white-rot fungus to degrade contaminants.

Bioremediation has been and is being successfully demonstrated at several environmentally impacted sites in Hawaii (see figure below).



Many of these processes have already demonstrated the technical and economic viability of bioremediation, and are building upon the existing technological base to strengthen the capabilities needed for a robust bioremediation industry in Hawaii. The University of Hawaii's role in capacity building and outreach has led to new courses, R&D projects, demonstration programs, and public outreach, which collectively have helped to build a workforce knowledgeable in bioremediation.

Many of the abovementioned projects were supported by the Agriculture-Based Remediation Program and the Biosystems Technology Program, funded by the U.S. Departments of Defense and Agriculture, and most have involved University of Hawaii researchers working in partnership with local companies and federal, state, or local agencies. As a result, Hawaii-based companies have gained long experience in traditional remediation technologies, and with the on going demonstration projects are developing expertise not only suitable for application in fragile Pacific Island ecosystems, but also in the industrial processes of developing countries.

C. *Biotechnology for Agricultural Diversification*

Agricultural biotechnology is an area in which Hawaii can sustainably diversity its traditional agricultural base. The expansion of R&D in this area and the potential for a high value niche market in future products hold tremendous promise for our economy.

There are many dimensions to this technology: a service sector, including winter nursery work, advancing products for other producers, and seed certification for regulatory or industry quality requirements; a basic R&D and technology transfer sector; product utilization by local agricultural producers; and innovative production, such as inorganic farming, to meet the emerging focus on medical and dietary requirements.

Hawaii agricultural research has already impacted plant and human biotechnology. The National Center for Food and Agricultural Policy (Washington, DC) has credited the development and adoption of transgenic papaya in Hawaii as providing one of the most dramatic illustrations of the potential for crop improvement through biotechnology. In the 1990s, Hawaiian papaya production was significantly declining due to a severe virus epidemic. Transformation of papaya with a Papaya ringspot virus coat protein gene produced successful protection against Hawaiian strains of the virus. Statewide production, which had fallen 45% from 1992 to 1998, rebounded by 35% from 1998 to 2000 and has attracted worldwide interest.

Hawaii is home to a seed industry that generates $36 million a year. Multinational agricultural companies use the Islands to grow newly-developed strains of corn and other crops in isolation, then distribute these seeds worldwide. The companies also use Hawaii as a test site for "transgenic" crops-plants with genes from other species inserted into their chromosomes. Most of these crops are corn, but local researchers also have acquired permits to grow transgenic soybeans and cotton, among other staples.

Organic farmers and growers of Hawaiian sweet corn are worried that drifting pollen from transgenic corn will mix with their crops. Scientists say pollen drift is a legitimate concern in "breadbasket" regions such as the Canadian and U.S. plains. But, they say, the Hawaii corn crop is small and scattered, and food crops are generally far from transgenic test plots. That's one reason most of the transgenic crops in Hawaii are corn, which bears little genetic resemblance to local plants.

An exciting possibility for Hawaii's future in agricultural biotechnology is in the ability of the molecular biologists to engineer plants to make industrial chemicals (biobased materials from renewable sources) and pharmaceuticals (biopharming – manufacturing drugs in plants). Both of these non-food uses have the potential to be less polluting, by-passing expensive, more contaminating operations and helping to stabilize non-renewable consumption. Generating pharmaceuticals from plants is very realistic for Hawaii because of the isolation it affords from the commodity crops (no chance of mix up in the food chain) and the lower volume needed (the final modified crop could be grown here). Drugs for cancer and some other ailments have lower volume demands that could be accommodated by available acreage in Hawaii. In addition, because of Hawaii's stable climate, they could be produced year round here, similar to what is done in a traditional factory operation.

American (and Hawaii) farmers appear to be caught in the middle of a battle between the United States and the European Union over genetically modified organisms (GMOs). The EU is one of the most important potential markets for these crops, two-thirds of which are grown in the United States, but impending EU regulations on biotech crops would seriously disrupt the flow of those exports to European markets.

The American case is basically that plant biotechnology has already dramatically boosted American farmers' productivity and lowered their costs, while at the same time helping them to protect the natural environment by reducing their use of agricultural chemicals and preventing soil erosion. Consumers have also benefited from lower prices and a healthier environment.

The EU has banned all foods containing GMOs on the basis of the "precautionary principle," under which regulators do not need to scientifically demonstrate that a biotech crop is unsafe before banning it; they only need to show that it has not been proved harmless.

However, scientific panels, as well as the U.S. Food and Drug Administration, have concluded that biotech foods are safe to eat. Studies of GMOs found no evidence that genetically modified foods posed any new risks to human health or the environment.

D. ***Mitigating Natural Disasters***

During the last decade, over 70 percent of all lives lost due to natural disasters occurred in the Asia-Pacific Region. Catastrophic human and economic losses due to tropical cyclones, floods, frequent earthquakes, volcanic eruptions, tsunamis, drought, wildfires, and events triggered by technological mishaps, plague the region. Losses from natural disasters in the Asia-Pacific region are increasing because of the continued confluence of the ***physical/natural environment***, which is constantly changing and punctuated by extreme geological and meteorological events, and ***society and its infrastructure***, which are expanding rapidly in hazard-prone regions.

As a consequence, the emphasis within both the Asia-Pacific and global disaster management communities is to shift the paradigm from ***reactive*** (i.e. focusing on response and recovery operations), to ***proactive*** (focusing on mitigation and preparedness). Additionally, hazard mitigation is now being viewed holistically as an integral part of urban/economic/societal development within a dynamic natural environment. Thus, it has become an issue of ***sustainable development*** and involves not only the disaster management community, but also those involved in urban planning and development, transportation and utilities, agriculture, business and economics, as well as scientists and educators, who together seek to create ***disaster resistant communities***.

The ***Pacific Disaster Center (PDC)***, a Maui-based disaster information research and support organization, is making key contributions to achieving the paradigm shift from ***reactive to proactive*** disaster management in the Asia-Pacific region. As illustrated in Figure 1, PDC is focused on bringing information innovation to disaster managers by taking maximum advantage of continuing advances in data collection techniques, modeling, computing and communications, as well as technologies for analysis and display of geo-spatial information to develop decision-support capabilities. PDC researches these technologies, develops tailored applications in the context of comprehensive disaster management, and assists in the transfer of validated and verified applications to end users.

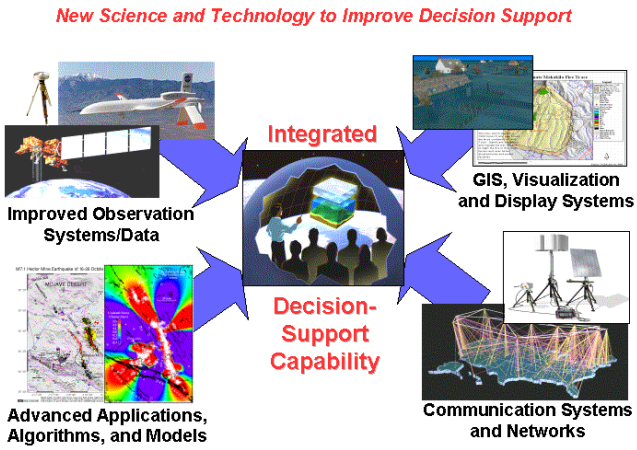


Figure 1: Science and Technology Integration for Disaster Management

Key technologies that PDC is working with, adapting, and/or developing include: new remote sensing platforms, techniques and data; geographic information systems and other geospatial information technologies; distributed information network technologies; and both holistic and interactive physical and predictive models.

Figure 2 illustrates the role PDC plays in integrating disparate data and information from multiple sources into cohesive input for decision-making toolsets that generate products in a variety of formats useable by a community of decision-makers for disaster management. The PDC will establish itself as a *testbed* for prototyping, evaluating, and integrating new applications of science and technology.

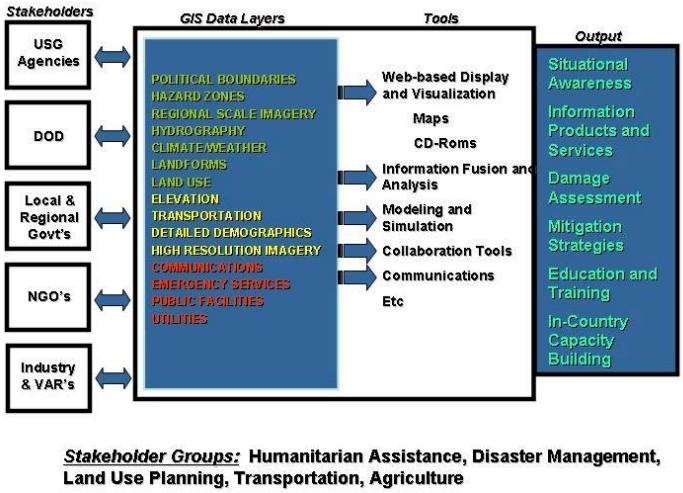


Figure 2: Integrated Decision Support System

Over the last year, the PDC has evolved into a public-private partnership between the PDC and the U.S. federal government, the East-West Center (EWC), and private industry. This partnership will enable the PDC to serve as a catalyst and incubator for expanded industry involvement for business and economic development in the State of Hawaii and the Asia Pacific Region, as well as to become a world leader and Center of Excellence in comprehensive disaster information management.

VII. Space-based Technology: Sea, Earth, Skies

A. *Remote Sensing for Terrestrial and Extra-Terrestrial Exploration*

State-of-the-art remote sensing equipment is being used by the Hawaii Institute of Geophysics and Planetology (HIGP) for a wide range of terrestrial and extra-terrestrial applications – to study active volcanoes from space, to determine the mineralogy of the surface of Mars, to characterize the topography of the sea floor, and even to search for and locate such interesting objects as the carrier Yorktown! Other instruments to remotely measure gases and aerosols, study the 3-D structure of ice sheets, and the subsurface characteristics of volcanoes using ultra-sound are currently under development at HIGP – all of which have potential spinoffs for private industry.

The scope of research activities at HIGP is wide ranging – from studies of the ocean floor to investigating the surfaces of other planets – but several characteristics are common to all. First, HIGP is playing a leadership role in large-scale missions and scientific projects, such as field programs (marine research cruises, land-based expeditions), space missions, and theoretical research into Earth and planetary processes. Secondly, HIGP is pioneering technological development of new instrumentation and analytical techniques, participation in instrument design teams, design and deployment of instrument networks, and the development of advanced data reduction and/or visualization software. Finally, HIGP is developing user-friendly, on-line information systems to provide data and products to the public, as well as to help train a highly-skilled technical workforce for Hawaii.

The vision of the Hawaii Institute of Geophysics and Planetology (HIGP) is to serve society at large by acquiring and disseminating new knowledge about the Earth and planets to the general public, as well as to strengthen the local economy by introducing cutting edge technologies to the private sector. Each year, HIGP scientists average almost $10 million in extramural Federal research funding, which alone makes HIGP an important contributor to our local economy.

Finally, HIGP is world renowned for its work in remote sensing. Through the Hawaii Space Grant program, HIGP researchers have developed a comprehensive training program in remote sensing, Geographic Information Systems (GIS), the use of

the Geographical Positioning System (GPS), Field Mapping, instrument design and construction, and communications technology.

Many scientists, engineers, educators, and students routinely use various components of these tools, but they also need hands-on training in how to combine them to evaluate earth system processes and environmental effects related to human and natural causes. HIGP is forging partnerships with other departments (e.g., Electrical Engineering) and local companies that produce remote sensing instruments and data, such as STI, NovaSol, and Geo InSight International.

This collaborative effort is also helping develop training courses and student internships, with the goal of developing a highly-trained local workforce for local companies. HIGP faculty and staff serve as technical advisors to Hawaii State Civil Defense, State Office of Planning, and the Department of Land and Natural Resources – helping them address a wide range of geophysical issues of relevance to our State – and provide invaluable assistance to many Federal agencies in Hawaii, including the U.S. Geological Survey, the Pacific Tsunami Warning Center, and the Pacific Disaster Center.

B. ***Reaching for the Stars***

Collision with asteroids presents a significant threat to humanity. A 300 meter asteroid impact in the Pacific would wipe out all seaboard cities. Although the mathematical probability of this occurring has generally been minimized, detecting all dangerous objects is a high priority for astronomy in the next ten years. The task is challenging, since the objects are faint and moving, requiring short exposures and scanning very large areas of sky.

The University of Hawaii's Institute of Astronomy (IfA) is mobilizing a wide-filed optical imaging system known as PAN-STARRS, which would generate digital images of the entire sky with unparalleled sensitivity and image quality to support a broad range of scientific research from solar system to galaxy studies. Presumably, its unique time-resolution capability will enable it to find "killer asteroids", supernovae, and other transient objects.

From a broader perspective, recent astronomical discoveries gleaned from the Mauna Kea Observatories have vastly changed our understanding of the Universe. Planets have been identified around other stars. Extremely distant galaxies have been found to be moving away from Earth at rates faster than predicted by recent theories. And explosive energy sources around the Cosmos have challenged our understanding of the forces driving both stellar and galactic evolution.

Recent discoveries of planetary systems around nearby stars have provided unequivocal evidence that solar systems are common in the Universe. A new type of instrument being developed by the University of Hawaii for use in the infrared – the Solar Systems Exploration Telescope (SSET) – will be used to study the origin of our solar system by measuring the size and composition of objects beyond the orbit of Pluto, as well as older solar systems around nearby stars and the formation of new solar systems around very young stars.

The University of Hawaii (UH) and The Institute for Astronomy (IfA) are currently developing "next generation" technology to explore these cosmic frontiers. For more than a century, the world's largest telescopes have doubled the scope of their predecessors by incorporating the latest advances in technology.

Today, digital technology affords new opportunities which UH and IfA are incorporating into the design and construction of a revolutionary optical and infrared telescope – the High Dynamic Range Telescope (HDRT) – that will combine the ability to observe faint and distant galaxies with an extremely sensitive tool to search for planets around other stars. The world's most powerful telescope for faint astronomical observations, HDRT will use technology that will reduce its visual impact when viewed from sea level, and will replace an older telescope currently on the summit so new areas will not be disturbed.

Further, as noted above, IfA is helping pioneer digital revolutions in wide-field imaging. Electronic detectors (CCDs) developed in the 1970s and 1980s helped revolutionize many areas of astronomy. These early detectors were too small for wide-field imaging. However, with the recent fall in the cost of CCDs, cameras with up to 100 million pixels have been deployed on a number of large telescopes, generating images of huge coverage and depth. The data obtained will enable astronomers to address fundamental questions in cosmology, such as the nature of dark matter and the ultimate fate of the Universe.

Targeting support for K-12 and undergraduate education, IfA and the Faulkes Telescope Corporation are collaborating to locate a two-meter telescope at the University of Hawaii's Haleakala High Altitude Observatory site on Maui. The largest telescope of its kind dedicated for educational purposes, the Faulkes Telescope will be operated remotely by students from control centers in the United Kingdom and at Maui Community College. Operating the telescope remotely over the Internet, students will be able to access observing data in "real time" from their classrooms. Astronomers in Hawaii and the UK plan to engage students in actual research projects that will be published in the scientific literature. The telescope will also be available to public and private schools around Hawaii, as well as to science programs at the University of Hawaii, the Bishop Museum, and other educational institutions statewide.

Research conducted with Hawaii's new cutting-edge telescopes will enable astronomers to address such age-old and intriguing questions as: *How many solar systems have Earth-like planets; How do solar systems, including our own, form; and What is the likelihood of life in other solar systems?*

VIII. Dynamic Derivatives of Dual-Use Technology[1]

A. *Opening Keynote Address by U.S. Senator Daniel K. Inouye (Hawaii)*

"We have much talent, skill, and ingenuity in Hawaii. And, we are fast gaining the critical mass of high technology companies which engage in dual tracks of defense research and technical support, and commercial activities. The holding of this conference, in and of itself, is testament to this growth. We are definitely coming of age. I hope that this conference will become an annual event.

We have come a long way over the past ten years. Ten years ago, there were no additional funds provided to the Pacific Missile Range, no new initiatives or "plus-ups". In fact, it was considered for base closure. Today, ten years later, $130 million is appropriated to PMRF, above and beyond its operating costs, to support the latest in cutting edge technology and expertise which supports a growing base of technology development on Kauai and our nation's defense mission.[2]

Ten years ago, Maui became the home of one of the nation's largest supercomputers with an appropriation of $19 million to the Air Force to support its telescope and surveillance work atop Haleakala.

Today, our own University of Hawaii is the operator with double the operating dollars and a growing number of initiatives to support our nation's defense computing needs, while growing technology on Maui. New projects like the Information Technology Center and Theater Undersea Warfare are locating on Maui to avail themselves of the services the supercomputer can provide. I could go on and on in a host of areas – from telemedicine advancements and fuel cell development to aquaculture and agriculture biotechnology.

Together, we have continued to move the baton forward. But, there is much more to do and to accomplish. Today, our nation is THE superpower of the world. Some may

[1] Excerpts from key note addresses and discussions at the State Conference in Dual-Use Technology in Honolulu, July 1-2, 2002, provide perhaps the best overall assessment of Hawaii's potentials.

[2] Since the Senator delivered his remarks at the State Duel-Use Technology conference, a timely report has been received, detailing progress at the Pacific Missile Range Facility which he has sponsored during his terms in office. The PMRF account is shown as a box in the next section of this report.

ask “WHY?” There are many reasons, but one is certain. Our nation has made and continues to make significant investments in technology, research and development, and commercialization.”

Box 1. Dual-Use Technology at Kauai’s PMRF

Located on the west coast of the island of Kauai, the Pacific Missile Range Facility provides the world’s largest multi-environment range capable of supporting surface, subsurface, air and space operations. With a thousand square miles of instrumented underwater range and over 42,000 square miles of controlled airspace, PMRF employs state-of-the-art technology to ensure the safe conduct and evaluation of both military training and T&E (testing and evaluation) missions.

Already the #1 employer on Kauai, with over 900 personnel and 277 contractors, PMRF is looking to expand its operations in a number of areas. An enhance launch capability to intercept military targets will also be able to support a microsatellites program that could send lightweight (under 100 Kg) payloads into low earth orbit. The US Navy is interested in building a 20 MW Free Electron Laser System to deter jet ski terrorists from attacking US Navy warships. With a shallow water minefield and expansive underwater range, PMRF hopes to expand testing of Mine Counter Measures as well as hypersonic underwater torpedoes. There also are plans to have an airship available in Hawaii to operate on the range, which will give the “lighter-than-air” community an opportunity to test new and innovative surveillance systems.

Operations at PMRF are being supported by private companies based at the West Kauai Technology Center. Established in 1999, the Center began construction on Phase II of its development – a 12,500-square-foot, $4.6-million facility that will bring the leaseable area in the center to 21,000 square feet and provide the critical mass of companies needed to insure the success of Kauai's dual use technology industry, as well as provide the catalyst for expansion and job creation in other high technology arenas such as information technologies, modeling and simulation. Future projects include Distant Learning with the UH "HITS" system and other "Virtual Universities" as well as partnerships with the Pacific Missile Range Facility, the Maui High Performance Computing Center, and the Natural Energy Laboratory of Hawaii.

B. ***Hawaii's Strategic Role in Technology Development in the Pacific (Randall Cieslak, representing Admiral Thomas Fargo, CC, U.S. Pacific Command)***

"…Let me discuss the importance of the great state of Hawaii to the Pacific and, of course, to the rest of the United States…Being a remote set of islands in the tropical zone has several advantages to research and technological development. Consider the natural resources. Hawaii's air is clear and its mountains are high, making for a terrific observation post for space surveillance. The Air Force uses Maui for its Air Force Maui Observation Station, and several universities and astronomical research centers have telescopes mounted on Mauna Kea on the Big Island for space research…

Hawaii's location and climate also make it conducive for space launch operations. Development of this capability is very controversial and has been proposed and rejected through the years due to environmental concerns, but there is really no better place on earth to launch rockets. Our Pacific Missile Range Facility at Barking Sands, Kauai takes advantage of these excellent conditions.

Another great resource associated with Hawaii's location is in ocean sciences, biology and botany. As soon as you go off shore and off the reef, the ocean is deep and warm near the surface. This makes for not only great conditions to study the ocean, but also excellent test conditions to assess seagoing vessels such as deep submergence vessels and surface effect ships. The semi-submerged platform, or SSP, that is used in some of our Towed Array Auxiliary Oceanographic Surveillance Ships, was developed here in Hawaii.

Hawaii's terrestrial environment also holds many opportunities to test and develop ground-based technology. (1) On the windward side of the islands we find thick mountainous jungles that are representative of more socially hostile locations. Hence technologies associated with moving and communicating in the jungle can be assessed. (2) The leeward side of the islands has a desert-like condition. With the vast lava fields on the Big Island, you have conditions that resemble some of the key planets of the solar system and the moon. Hence, technologies associated with visiting the moon and planets can be tested here…

As I am sure you are aware, Hawaii prides itself as the "the Health State" with its clean environment, and preponderance of excellent doctors and health care professionals

who just like living in paradise. More importantly, there is tremendous potential here in our state for advancing medical-based technology. The Pacific Command uses Internet technology to connect field surgeons to in-garrison doctors and established medical facilities…

I'm going to transition from Hawaii's physical environment to the cyber environment of the Maui High Performance Computing Center. High performance computers can process images from observatories throughout Hawaii to help detect small and distant space objects such as comets, asteroids and meteors. Through high-speed fiber optic connectivity, the Computing Center can process data from all over the world…

The most critical resource needed to support command and control of our military assets, as well as communication and cooperation with our Asian neighbors, is information technology. In cyberspace, the concept of physical location goes away. As a hub for both terrestrial communication through submarine cables, and satellite communication through satellite ground stations, Hawaii is an important interface between public information infrastructure and the austere environment of the ocean, the Pacific Island nations and much of Asia…

Unlike many of the physical technologies such as material sciences where the defense and government R&D lead to products that are useful to the public, such as Velcro, Kevlar, and the Jet Airplane, the tables are turned when it comes to Information Technology. It is true that the origins of the internet were with the Department of Defense, but it was only through close cooperation with the academic community that the network was able to take on the form that we know today, and with just enough structure to work, but not enough structure to stifle creativity, ingenuity and innovation.

Now commercial industry is doing the R&D, making the advancements, coming up with new and innovative ways to share information and knowledge beyond the bounds of the classroom and library. So we look to you in industry to advance information technology and help us implement it in the cause of national security and defense…

Some of the more specific technologies that are conducive to dual use technology transfer potentially here in Hawaii are:

- Distributed Learning Technology – Finding new ways to get fresh, innovative information to the computer screen, how to visualize it and get it into the person's brain where it becomes true knowledge.
- Cyber Identity – Maturing biometric technology to create a digital human signature as unique as a DNA sample so that the person's digital attributes are enough to positively identify the individual.
- Access control – Being able to discern between what an individual is allowed to do or not do, based upon his or her identity.
- Dynamic bandwidth management – to enable controlled sharing of available network capacity.

However, even the power of information technology will not be enough to provide the warmth of our soft air, the refreshment of our beaches and the Aloha of the Hawaiian people."

C. *Concluding Assessment of Hawaii's Dual-Use Technology Potentials*

- It would appear particularly timely and opportune for a major effort for Hawaii agencies and firms to activate cooperative or collaborative arrangements with Federal defense and non-defense programs where there is a common set of knowledge, skills, and aspirations.

- This cooperative approach between Federal and State establishments is timely in view of the necessity and urgency to deploy the Nation's total resources to meet its security objectives. It is opportune in that Hawaii's need for economic diversification can be realized through engagement of human, physical, and natural resources in areas of national priority, as exemplified during conference presentations.

- Public-private partnerships should be established in areas of mutual interest and benefit, with the strong caveat that partners share visions, objectives and commitments that are critical in technology development and transfer of technology into commercial opportunities.

- For commercialization of cooperative Federal-state technology output, development of a cluster of companies to provide a "critical mass" for sustained high-tech development would be significantly advantageous. The location of a particular technology industry in an area also generates business clustering of support industries. An industrial cluster creates demand for local suppliers who can quickly provide materials and services. An industry concentration also allows both labor and capital resources to flow more freely between firms within a region. Company developments at the West Kauai (Waimea) Technology Center, centered around the Pacific Missile Range Facility, are clear-cut examples of a dynamic cluster approach. Similar potentials also exist at the Maui High Performance Computer Center, the University Research Park at Hilo, and Kakaako Medical and Biotechnology Research Center in Honolulu.

- Hawaii is home to several national assets utilizing state-of-the-art technologies:
    - the Natural Energy Laboratory of Hawaii is a unique ocean research park and development center for renewable energy research and deployment;
    - the Maui High Performance Computing Center has one of the most powerful supercomputers in the world, with capabilities for high-speed communication infrastructure such as data archiving, telemedicine, defense testing and evaluation, and remote sensing;
    - the Pacific Disaster Management Center provides emergency management-disaster mitigation, preparation, response and recovery-within the Pacific and Indian Ocean regions;
    - the Pacific Missile Range Facility provides the world's largest multi-environment range capable of supporting surface, subsurface, air and space operations; and
    - the Mauna Kea observatories are the world's premier facilities for astronomy and astrophysical research.
- Each of these physical assets, with appropriate reconfiguration as needed, can provide the basis for state of the art technology initiatives to attain both national and state goals. For both Federal and State partners, it will be necessary to
    - work with industry (e.g., HTTA, Chambers) and the University (Vice Presidents for Research and Technology Development), to (1) help propose promising areas of research which support national security and economic development objectives, and (2) determine market opportunities for economic development based on University research;
    - work with financial executives and entrepreneurs in Hawaii and on the mainland to ensure that tech-oriented business ventures meet commercialization requirements in terms of profitability, product recognition, and service quality;

- work with industry and educational institutions at all levels to determine needed improvements to advance workforce skills, and to determine how industry might contribute to this endeavor; and
- energize a collaborative effort between all sectors of government, the University of Hawaii, and private enterprise, to encourage Federal support for the State's world premier facilities, as well as for research and development advances in such areas of competitive advantage as ocean science, remote sensing, data archiving, telemedicine, telecommunications, and biotechnology.

Acknowledgments:
Our deep appreciation to the many individuals and agencies throughout the State for contributions to this report. Our thanks to Jim Crisafulli and Michelle Kim for their valued assistance. However, any interpretations or opinions expressed are those of the editor and do not necessarily reflect those of the Department or the state government of Hawaii.

--Shelley M. Mark, Senior Advisor